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Chemical Composition of Potatoes. I. Preliminary Studies on the Relationships Between Specific Gravity and the Nitrogenous Constituents

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SUMMARY

Katahdin potatoes (1959 crop) were placed in storage at 38°F. Monthly samples were removed and separated into three specific-gravity levels—high, intermediate, and low. Total solids changed but little in storage, indicating that shrinkage is due to a loss of both solids and water in the ratio in the original composition. Total and soluble nitrogen analyses over 10 months demonstrated an inverse relationship between total solids and these constituents when calculated on a moisture-free basis. The nitrogen per gram of fresh weight shows no significant difference between samples of different solids contents. Therefore, the apparent inverse relationship on a moisture-free basis is due to the storage of other constituents, presumed to be principally starch, in the case of high-solids potatoes. About 60–62% of the nitrogen is extracted by 70% by weight ethanol. Subsampling of large lots of potatoes for specific-gravity studies is extremely difficult. All data should be checked for variations from sampling error.

Studies on the nitrogenous constituents of potatoes have been reported by several researchers. As noted (Neuberger and Sanger, 1942), their results are difficult to interpret since the nitrogen value recorded in most of the experiments was total nitrogen only. Neuberger and Sanger (1942) attempted to characterize the different nitrogenous fractions and reported data for a number of varieties showing fairly wide variations in total nitrogen and in the relative proportions of the different fractions.

Other workers, including Lampitt and Goldenberg (1940), have reported total nitrogen analyses obtained on potatoes from different countries. Representative of studies on the nitrogenous fractions are papers by Steward and Street (1946) and Kaspers (1959) on amides; Dent *et al.* (1947), Steward *et al.* (1949), Zacharius *et al.* (1952), Kaspers (1959) and Szalai (1959) on amino acids; and Osborne and Campbell (1896), Groot (1946), and Chick and Slack (1949) on the proteins.

Problems of extraction of potatoes for amino acid analyses were discussed by Talley *et al.* (1958), who showed that, unless continued and complete extractions were made with 70% by weight ethanol, the picture of the relative amounts of the amino acids would be distorted by differences in rate of extraction of the several amino acids.

None of these reports attempted to show the relationships of specific gravity (total solids) and the composition of potatoes. Since a greater percentage of each crop is processed, this relationship is important because of the use of specific gravity as a measure of suitability for a specific product. This paper demonstrates the relationship of specific gravity and the nitrogenous constituents of potatoes, and points out some of the problems involved in such studies.

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MATERIALS AND METHODS

Katahdin potatoes, grown during the 1959 season at the University of Maine Agricultural Experiment Station, Presque Isle, Maine, were furnished by the University. One ton of potatoes, the controls for an experiment on methods of killing tops, were stored at 38°F in 60-lb boxes selected on a random basis in one of the University storage houses beginning September 25, 1959. A sample consisting of two of these boxes was immediately sent to Philadelphia to determine the initial composition. Each month for nine consecutive months, a 120-lb sample was removed from storage and sent to our laboratory for analysis. Table 1 presents the data of sampling, average specific gravities, moisture values and relative weights of the samples.

Table 1. Weight-volume data for 38°F storage samples.

Date of sampling	Time (months)	Av specific gravity (potato hydrometer)[a]	Moisture[b]	Relative weight (measure of shrinkage)
Sep. 25, 1959	0	1.066	83.1	100.0
Oct. 16	1	1.070	82.2	98.5
Nov. 17	2	1.065	83.3	98.4
Dec. 28	3[c]	1.066	83.1	98.1
Jan. 18, 1960	4	1.069	82.4	97.3
Feb. 17	5	1.067	82.8	97.3
Mar. 17	6	1.066	83.1	95.4
Apr. 18	7	1.065	83.3	94.6
May 14	8	1.068	82.6	94.5
June 16	9[d]	1.065	83.3	93.1

[a] Taken on 8-lb sample from shipment before separation into the several specific-gravity fractions.

[b] Read from hydrometer conversion graph.

[c] First December shipment (December 13), frozen in transit.

[d] This sample removed from 38°F storage on May 16, 1960, and placed in 45°F storage until June sample taken. Definite evidence of sprouting.

Upon arrival, the average specific gravity of an 8-lb sample was determined with a N.P.C.I. (National Potato Chip Institute) potato hydrometer. Using this specific gravity as the median, the samples were separated into six fractions with salt brines of the appropriate concentration. Each fraction represented a range of 0.003 specific-gravity units, as shown in Table 2. The highest, an intermediate, numbered 3, and the lowest specific-gravity fractions were selected for analysis. The three other fractions were discarded. Samples for analysis were taken by arranging each fraction according to size of potatoes and selecting an equal number of tubers of each size.

Table 2. Example of ranges of specific gravity.[a]

Fraction	Specific gravity range[b]	Selected for analysis	% of sample	Av sp gr (hydrometer)
1	>1.072	yes	11.00	1.078
2	1.069–1.072	no	13.07	1.072
3	1.066–1.069	yes	24.59	1.069
4	1.063–1.066	no	16.72	1.067
5	1.060–1.063	no	14.40	1.063
6	<1.060	yes	20.22	1.060

[a] Sample No. 1, September.

[b] These ranges are the limits of the specific gravities of the salt brines employed.

The samples from each fraction were peeled for 20 seconds in an abrasive peeler (Toledo Vegetable Peeler, Model No. A1-15). The eyes were not removed, but damaged spots were hand trimmed. Average peeling loss was about 6%. Potatoes were peeled so the samples would be nearer to the condition of potatoes when processed commercially or prepared for home use.

Each sample was extracted with 70% by weight ethanol based upon the method of Talley *et al.* (1958). An accurately weighed sample (1200–1400 g) of peeled potatoes was placed in a 1-gal Waring Blendor, and sufficient absolute ethanol was added (about 2400 g) to make 70% by weight ethanol when mixed with the water in the potatoes. With a dipper, accurately weighed aliquots of the slurry were removed after the grinding operation (1.5 min at high speed, then slowed to minimum running speed) for determination of total nitrogen and total solids and for extraction for amino acid, organic acid, and soluble nitrogen determinations. For the extraction sample, the aliquot removed corresponded to 50 g fresh weight of potatoes. This sample was first carried through 5 batchwise extractions with 70% by weight ethanol and finally through two 24-hour Soxhlet extractions. The combined extracts were concentrated in rotary evaporators at less than 40°C. The extract was then made to 500 ml with water and ethanol so that the resulting solution was 20% by weight ethanol (self-preserving).

Total solids were determined on about 18 to 20 g accurately weighed slurry samples (equivalent to 4 to 7% solids in the slurry). Drying for 2 hours at 60°C in a mechanical convection oven was carried out to remove the ethanol and part of the water; then 3 hours at 130°C resulted in constant weight.

Total nitrogen was determined by micro-Kjeldahl digestion using mercuric oxide as a catalyst and distillation by means of the A.S.T.M. official distillation equipment into saturated boric acid followed by titration with standard acid solution. To minimize foaming during digestion of the slurries, about 5 ml of distilled water and a few drops of concentrated sulfuric acid were added to each sample, and the samples were boiled down until the residue began to brown. The catalyst and sulfuric acid were then added, and the digestion continued in the usual manner (Burroughs, 1960).

Soluble-nitrogen determinations were made by the same procedure, using aliquots of the extract prepared for amino acid and organic acid determinations.

Insoluble nitrogen (protein nitrogen) was calculated from the difference between total nitrogen and extractable nitrogen.

All analytical data are the result of at least two replicates.

The amino acid and organic acid compositions of these samples will be reported in future papers.

RESULTS AND DISCUSSION

Table 1 shows a progressive loss in weight during storage. The lack of change in solids content over the same period indicates that both solids and water are lost in the ratio of the original composition. This verifies the observation of Treadway *et al.* (1949) on the effects of storage on starch and sugars. Therefore, conclusions based on relative solids in the different specific-gravity fractions are valid.

Tables 3, 4, and 5 present the data on solids and nitrogen obtained for the high, intermediate, and low specific-gravity fractions. The June sample had been placed in 45°F storage at the time of the May sampling, which accounts for the small changes in nitrogen composition.

The 6.9% shrinkage indicated in Table 1 should result in a loss of solids of about 1.4%. This in turn should result in a gain in total nitrogen of about 0.02% during

Table 3. The solids and nitrogen composition of the high-specific-gravity fraction.

Month	% solids	% of sample	% total N (MFB)	mg total N/g fresh wt	% N in extract (MFB)	mg extractable N/g fresh wt	% insol N (MFB)	mg insol N/g fresh wt	Insol N / Total N (MFB)
Sep.	19.85	11.00	1.79	3.44	0.99	1.97	0.80	1.47	0.45
Oct.	19.20	10.30	1.77	3.38	1.03	1.96	0.74	1.42	0.42
Nov.	18.28	19.37	1.72	3.08	1.08	1.92	0.64	1.16	0.37
Dec.	18.77	22.51	1.72	3.22	1.12	2.09	0.60	1.13	0.35
Jan.	18.85	12.95	1.72	3.24	1.13	2.12	0.59	1.12	0.34
Feb.	19.05	7.66	1.72	3.27	1.04	1.99	0.68	1.28	0.40
Mar.	18.70	10.14	1.80	3.34	1.09	2.03	0.71	1.31	0.39
Apr.	18.80	14.77	1.76	3.32	1.06	2.00	0.70	1.32	0.40
May	18.98	11.54	1.79	3.40	1.11	2.11	0.68	1.29	0.38
June	18.44	25.24	1.91	3.52	1.19	2.19	0.72	1.33	0.38
Average	....	....	1.77	3.32	1.08	2.04	0.69	1.28	0.39

Table 4. The solids and nitrogen composition of the intermediate-specific-gravity fraction.

Month	% solids	% of sample	% total N (MFB)	mg total N/g fresh wt	% N in extract (MFB)	mg extractable N/g fresh wt	% insol N (MFB)	mg insol N/g fresh wt	Insol N / Total N (MFB)
Sep.	18.04	24.59	1.86	3.36	1.05	1.89	0.81	1.47	0.44
Oct.	17.68	17.85	1.95	3.44	1.14	2.01	0.81	1.43	0.42
Nov.	16.42	18.17	1.99	3.27	1.34	2.20	0.65	1.07	0.33
Dec.	16.98	20.99	2.03	3.45	1.31	2.23	0.72	1.22	0.35
Jan.	17.43	13.74	1.76	3.07	1.19	2.07	0.57	1.00	0.32
Feb.	17.62	22.14	1.88	3.32	1.18	2.06	0.70	1.26	0.37
Mar.	17.95	18.21	2.01	3.41	1.33	2.28	0.68	1.13	0.34
Apr.	17.05	12.02	2.01	3.43	1.24	2.11	0.87	1.22	0.43
May	17.43	17.78	1.97	3.47	1.16	2.03	0.81	1.44	0.41
June	16.87	16.18	2.14	3.60	1.35	2.28	0.79	1.32	0.37
Average	....	....	1.96	3.38	1.23	2.12	0.74	1.26	0.38

storage. Statistical analysis of the data, including the duplicate and triplicate values obtained, using standard deviations, indicate that this value (0.02%) would not be significant, and the data could not be interpreted as showing this small gain.

It is apparent that total nitrogen, soluble nitrogen, and insoluble nitrogen on a moisture-free basis are inversely related to the solids content. It is also apparent that, regardless of the solids content, the mg of nitrogen per g of fresh tissue is constant, within the experimental limits of error. These results can be interpreted that, for this variety of potato (Katahdin), all of the lots of tubers in this experiment stored essentially a constant amount of nitrogen and that the nitrogen did not vary appreciably throughout the storage period. The apparent inverse relationship between solids content and content of all forms of nitrogen on a moisture-free basis is the result of an increased content of some other dry matter constituent, presumably starch. Therefore, the nutritional value of a specific lot of potatoes, as measured by total, soluble, and insoluble nitrogen, is the same, whether it is from a fraction of high, intermediate, or low solids content. A dehydrated product produced from high-solids potatoes, however, would have a lower relative nitrogen value. Because there are known and unknown effects from environment and variety, care must be taken in generalizing on the relationship of specific gravity and nitrogen content until much more data have been obtained.

It is interesting that to be reconstituted, flakes produced from low-solids potatoes require a higher ratio of water than flakes from high-solids potatoes, Cording and Sullivan (1960). For these two products, the end result would approach the same nitrogen content per gram of reconstituted mashed potato.

The tables also indicate that, within a particular specific-gravity fraction, the relation of nitrogen level to actual solids content is more difficult to see. The reason is probably the relative insensitivity of the methods for determining the solids. It was for this reason, as well as to lessen the number of samples and to accentuate the differences due to specific gravity, that only the three specific-gravity fractions were studied. Close inspection of the data, however, indicates the same inverse relationship between solids and the *insoluble* nitrogen contents in all specific-gravity fractions.

The relationship of insoluble nitrogen to total nitrogen remains fairly constant, irrespective of solids content. The value of 38–40%, as presented, is corroborated by values previously reported (Chick and Slack, 1949).

The problem of sampling potatoes for specific-gravity studies is pointed up by the variation in the percentage of the sample in each fraction resulting from the brining operation. The variation, e.g., 3.68–25.32%

Table 5. The solids and nitrogen composition of low-specific-gravity fraction.

Month	% solids	% of sample	% total N (MFB)	mg total N/g fresh wt	% N in extract (MFB)	mg extractable N/g fresh wt	% insol N (MFB)	mg insol N/g fresh wt	Insol N / Total N (MFB)
Sep.	15.57	20.22	2.22	3.50	1.26	1.96	0.96	1.54	0.43
Oct.	14.32	12.36	2.32	3.34	1.39	1.99	0.93	1.35	0.40
Nov.	13.93	14.05	2.23	3.08	1.51	2.10	0.72	0.98	0.32
Dec.	14.50	3.68	2.34	3.39	1.40	2.04	0.94	1.35	0.40
Jan.	15.13	17.24	2.24	3.38	1.59	2.37	0.65	1.01	0.29
Feb.	15.48	25.32	2.21	3.42	1.34	2.07	0.87	1.35	0.39
Mar.	14.94	11.11	2.29	3.42	1.48	2.21	0.81	1.16	0.35
Apr.	14.91	23.84	2.26	3.37	1.43	2.14	0.83	1.23	0.37
May	15.31	22.64	2.23	3.28	1.38	2.12	0.85	1.16	0.38
June	14.67	12.52	2.43	3.56	1.54	2.27	0.89	1.29	0.37
Average	....	....	2.28	3.37	1.43	2.13	0.85	1.24	0.37

in the low-specific-gravity fraction (Table 5), results from the variation in the median specific gravity of the subsamples taken from storage for analysis, and is probably due to the inherent difficulty of selecting entirely representative samples from the original one-ton lot. It should be noted that this variation appears not to affect the over-all relation of nitrogen content to solids content, but the possibility exists that more accurate data could be obtained if this factor were eliminated. For this reason, future studies will be made on samples separated into the different specific-gravity levels before placement in storage.

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